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ORIGINAL ARTICLE

Medicine Science 2022;11(2):656-65

Medicine Science International Medical Journal

Posterior root tear of the medial and lateral meniscus on magnetic resonance imaging of 10,980 knee

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Received 27 January 2022; Accepted 10 February 2022
Available online 14.03.2022 with doi: 10.5455/medscience.2022.01.020

Abstract

It is aimed in this study study to determine the incidence of meniscus root tear in the knee and its effects on additional injuries related to the degree of meniscal extrusion, degree of chondrosis, malalingment and subchondral insufficiency fractures of the knee (SIFK). A total of 277 patients with a meniscal root tear detected on knee magnetic resonance imaging (MRI) taken between January 2011 and December 2020 were retrospectively analyzed. The severity of meniscal extrusion, osteophyte size and alignment were measured on MRI. Subchondral insufficiency fracture medial compartment osteoarthritis, lateral compartment osteoarthritis, additional ligament and meniscal injuries were recorded. The mean medial meniscal extrusion was 4.91 ± 2.2 mm and the mean lateral meniscal extrusion was 3.07 ± 1.56. While the mechanical alignment was 4.05 ± 2.24 degree varus in the patients with medial meniscus root tear, 1.88 ± 3.55 degree valgus in those with lateral meniscus injury. The mean size of tibial osteophyte was 2.51 ± 1.06 mm. In arthrosis grading conducted by using the International Cartilage Repair Society (ICRS) MRI-based grading system, the meniscal extrusion was measured to be 3.09 ± 1.1 mm in grade I, 5.04 ± 2.25 mm in grade II, 5.8 ± 2.01 in grade III and 6.05 ± 1.2 mm in grade 4. A statistically significant relationship was found between meniscal extrusion and age and mechanical alignment ($p < 0.001$). It was determined that, the patients having high-grade meniscal extrusion suffered from high-grade chondrosis, varus and SIF lesions. It was concluded that meniscus posterior root tear (MPRT) induces meniscal extrusion (MME) leading to subchondral insufficiency fracture of the knee, varus, and gonarthrosis.

Keywords: Meniscus root tear, Insufficiency fracture of the knee, Chondrosis

Introduction

Primary osteoarthritis (OA) is an etiologically multifactorial joint disease [1]. According to MRI studies, tibia-femoral cartilage, joint fluid, meniscus integrity and the location of the meniscus contribute to the formation of the joint space [2]. It is known that cartilage loss, cartilage defects, and meniscal tears and extrusion promote osteoarthritis, however the relative effect of each on OA progression remains unknown and is currently under investigation. The relationship between the development of OA and factors such as meniscus posterior root tears and meniscal extrusion degree and has been limitedly addressed in the literature.

Meniscus injuries in the knee are prevalent [1]. Meniscus tears are not always associated with trauma. Acute meniscal tears most commonly caused by twisting injuries. Chronic degenerative tears, particularly in elderly patients, can develop even as a result of minimal twisting [1]. Root tears occur in the meniscus incision due to bone or soft tissue avulsion [2]. Medial meniscus (MM) posterior root tear (MMPRT) is described to be a full radial tear or bone avulsion located in 9 mm of the posterior insertion of the MM [3,4].

The meniscal collagen fibril bundles mainly extend peripherally, and the radial fibril arrangement support the meniscus to resist circumferential stresses in the course of load transmission. Disruptions taking place perpendicular to the radial orientation

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leads to greatest disruption in the meniscal function, while tears parallel to the collagen fibrils induce minor disruption [5]. Meniscal tears can change the dynamics of force transmission in the knee and eventually cause meniscal extrusion, development of meniscal tears, and hyaline cartilage defects. Nonetheless, medial meniscal extrusion severity differs among patients with root tear. It has been reported that the knee biomechanics was comparable between patients with meniscus root tear and those with total meniscectomy. Those tears are surgically repaired for the protection of the knee from heightened impairment.

MRI is the most precise non-invasive technique to diagnose meniscus tears. MRI presents higher sensitivity (86-96%) and specificity (84-94%) in detecting meniscal tears. However, it is possible that MRI may fail to detect medial meniscus posterior root tears and its sensitivity (66.3%) is lower for these tears compared to other meniscus tears [6]. The assessment of the existence of meniscal extrusion in the coronal plane is a secondary indication asserted to help for detecting root tears [7,8].

SIFK is a non-traumatic fracture that occurs just below the articular cartilage as an result of subchondral stress of the knee, mostly connected to meniscal insufficiency [9]. Non-traumatic fractures or injuries in the subchondral bone cause increased intramedullary edema, which in turn leads intraosseous pressure to increase. Thus, this progression results in ischemia and osteonecrosis in the subchondral bone. Patients suffering from SIFK can be healed using conservative therapy [10]. There are differences between SIFK and secondary osteonecrosis with respect to risk factors, etiology, and imaging [11].

Our hypothesis is that as extrusion increases in meniscus root tear, since the normal knee biomechanics alters, loading and contact pressure in the femorotibial axis increases, which can cause unicompartmental arthrosis. In the present study, it is aimed to determine the incidence of meniscus root tear and associated additional injuries in the knee and to assess the relationship between meniscal root tear and the degree of meniscal extrusion, degree of chondrosis, malalingment and subchondral insufficiency fractures.

Materials and Methods

The medical records of the patients who underwent knee MRI for any reason between January 2011 and December 2020 in Tokat Gaziosmanpasa University Hospital were retrospectively reviewed using the electronic patient record system. The PACS software was used for all reconstructions and measurements (Sectra Workstation IDS7, Version 21.2.11.6289, ©2019 Sectra AB). The study adhered to the principles outlined in the Declaration of Helsinki.

Participants

Knee MRIs available in the PACS system of our hospital were scanned in terms of meniscus root tear. The patients were grouped in terms of age as 1-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and 80-89 (Figure 1). The patients who were unanimously diagnosed with meniscal root tear on MRI by two orthopedic doctors with at least 10 years of experience were enrolled in the study.

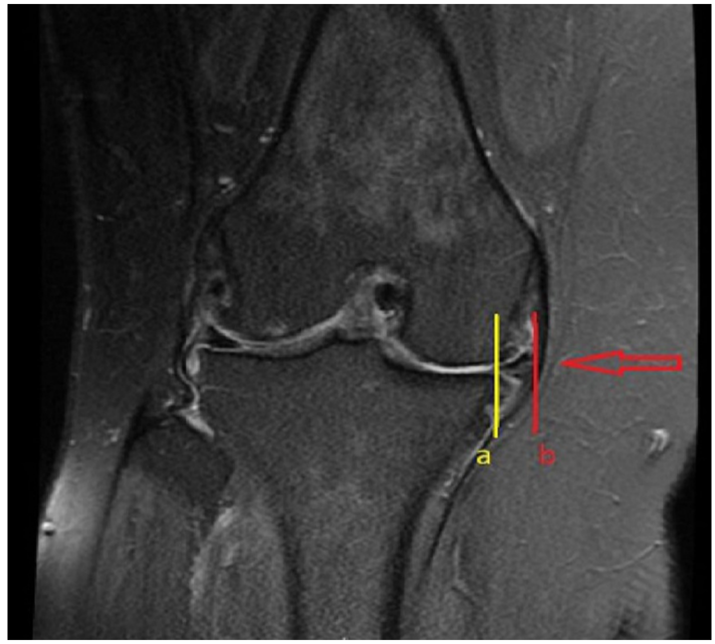

Figure 1. Measurement of medial meniscal extrusion. Extrusion is determined by measuring the distance in mm between the two perpendicular lines in the image showing the femoral medial condyle. First, a proper slice is selected in the coronal plane magnetic resonance imaging. Second, the exclusion of osteophytes are performed. Third, a perpendicular line (a) is drawn at a point at which the medial tibial plateau transitions from horizontal to vertical, then another perpendicular line (b) is drawn intersecting the outermost edge of the medial meniscus. The distance between the lines (a) and (b) is measured.

Exclusion criteria: The MRI images taken after an acute event associated with high-energy trauma, fracture, or high-grade contusion, the patients whose MRI image is not of sufficient quality to evaluate a meniscus root tear, those who underwent surgical operation including knee meniscectomy, and those with infection or tumor in the knee region were excluded from the study. As described in previous studies in the literature, The presence of SIFK was assessed using T2-fat suppression magnetic resonance imaging [9] and the SIFK was graded according to the Koshino classification [12]. The meniscal tears and extrusions were classified as extrusion none, mild (< 3 mm), moderate (3–5 mm), or severe (> 5 mm) [13–15]. The identification of medial/lateral meniscal tears with/without extrusions were performed on the coronal and fat suppressed T2-weighted sequences. Additional medial and lateral meniscal tear and ligament injures to the knee accompanying the meniscus root tear were scanned and the type of the tear was recorded

A mid-coronal plane, described as the slice having the largest area of the medial spine, was used to assess meniscal extrusion. If its use is difficult, the slice having the widest tibial plateau was selected [5,16]. Figure 1 shows the measurement of meniscal extrusion.

Medial knee compartments and lateral compartment chondrosis were classified according to the International Cartilage Repair Society (ICRS) grading system [16]. The chondrosis was graded in the medial and lateral knee compartments. Osteophyte size was measured using the coronal plane MRI as exhibited in Figure 2.

The femur tibial angle was calculated by the method suggested by Iranpour-Boroujeni et al. (Figure 3) [17].

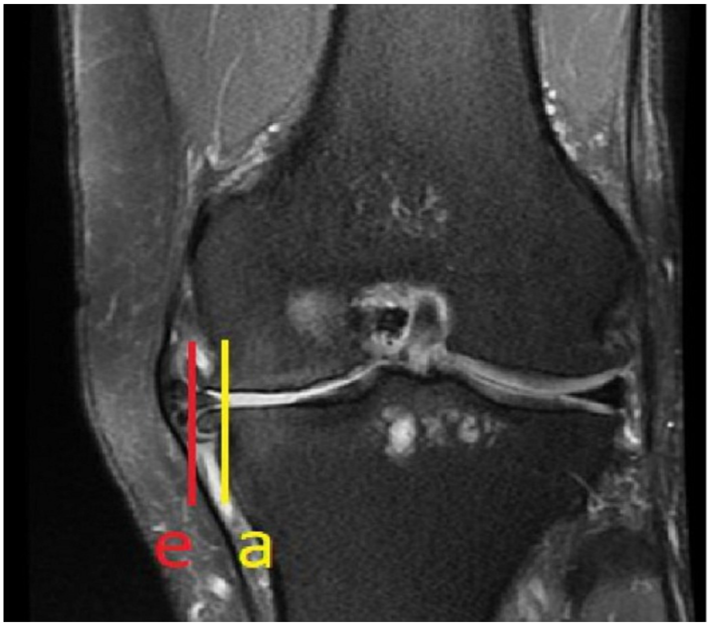

Figure 2. Measurement of tibial osteophyte size. The length between the vertical line (a) and the line (e) which represents the end point of the osteophyte on the medial side of the tibial proximal articular surface is measured.

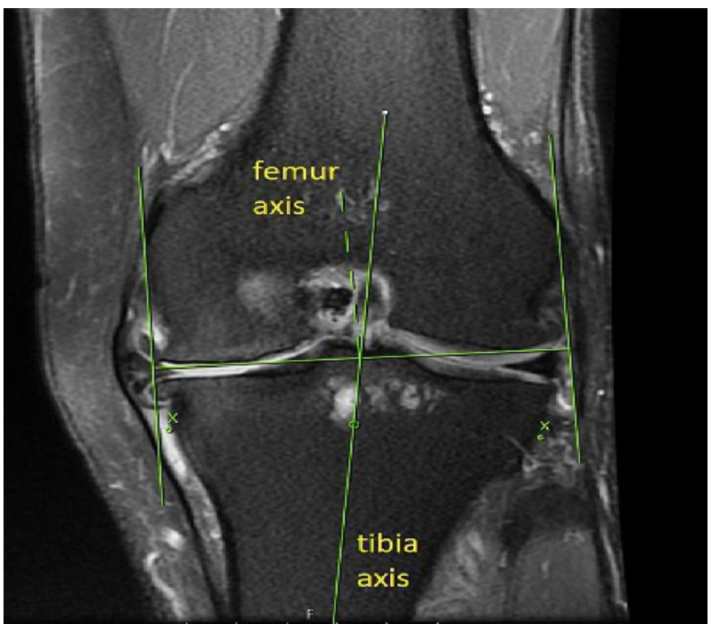

Figure 3. Determination of the femur tibial angle by the method proposed by Iranpour-Boroujeni et al. In the method, first, the mid-coronal axis is found, second, a line connecting the condyles is drawn. Third, a line is drawn perpendicular to the line joining the condyles and the midpoint of these perpendiculars is found. Then, the alignment angle which is a negative number for valgus is calculated.

Statistical Analysis

The data are presented as mean ± standard deviation or frequency and percent. Student's t test or one way analysis of variance were employed for the comparison of the continuous normal data between/among groups. Chi-Square test was used for the comparison of the categorical data between/among groups. Categorical data were presented as a count and percentage. The power of variables for the prediction of significant meniscal extrusion classification were determined applying receiver operating characteristic (ROC) analysis. Any p-valueless than 0.05 was regarded to be significant. The SPSS 19 software was used to analyze the data (IBM SPSS Statistics 19, SPSS inc., an IBM Co., Somers, NY)

Results

The total number of knees reviewed in the study was 10,980. It was found that the mean age of the patients was 56.82 ± 11.18 years. It was found that there were 265 (95.7%) patients with medial meniscal root tears, 5 (1.8%) patients with lateral meniscus root tears, and 7 (2.5%) patients with both medial and lateral meniscus root tears. Meniscus root tear incidence detected on MRI was 3.32% in females and 1.39% in males. The overall incidence of meniscal root tear across all MRI was found to be 2.25%.

Figure 4 presents the age group and gender distribution of all patients whose knee MRI were retrospectively reviewed in our study. Of the patients with meniscus tear, the mean age was 53 ± 10.93 years in those with lateral meniscus posterior root tear while 56.76 ± 11.05 years in those with medial meniscus posterior root tear. The patients with lateral meniscus tear were younger. The meniscal root tear was accompanied mostly by horizontal meniscus tear in both medial meniscus (12.8%) and lateral meniscus (6.8%) cases. While 69.8% of the medial meniscus root tear was not accompanied by additional ligament injury, this rate was much lower in the lateral one (28.6%). The most common concomitant ligament injury to meniscus root tear was anterior cruciate ligament (ACL) rupture (Table 1). Lateral meniscus root tear was more frequently seen in both young patients and the patients with additional ligament injuries. In addition, SIFK was detected in 28.5% (79) of the patients with meniscus root tear.

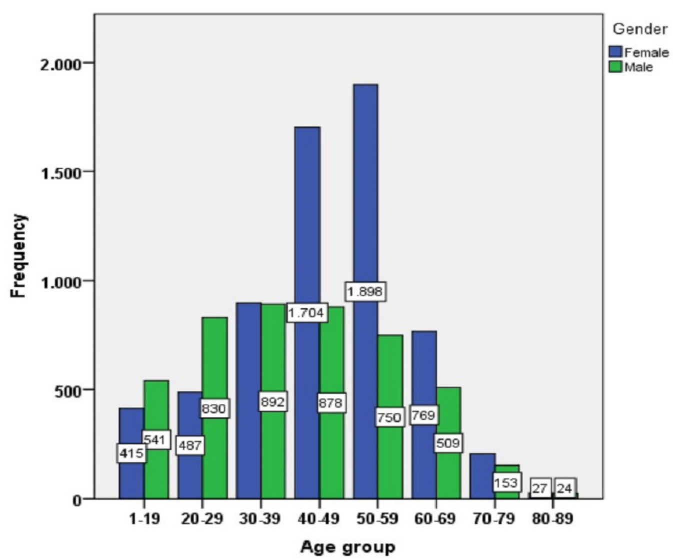

Figure 4. Distribution of all patients whose MRIs were reviewed in terms of gender and age group

It was detected that five patients having both medial and lateral meniscus root tears did not have meniscal extrusion, whereas in the patients having medial meniscus root tear, the classification of meniscal extrusion revealed that there were 119 (44.9%) severe, 91 (34.3%) Moderate and 50 (18.9%) mild extrusion. Of the patients with grade 3 medial compartment arthrosis (MKOA), 45.6% had severe meniscal extrusion, 50% of the patients with grade 1 MKOA had mild meniscal extrusion (Table 2). It was determined that meniscal extrusion increased with increasing the degree of chondrosis. The mean medial meniscal extrusion was 4.89 ± 2.22

mm in the patients with medial meniscus posterior root tear, the mean lateral meniscal extrusion was 3.2 ± 1.7 mm in the patients with lateral meniscus posterior root tear. Whereas the mean medial meniscal extrusion was 5.94 ± 1.22 mm and the mean lateral meniscal extrusion was 2.97 ± 1.58 mm in the patients with both medial and lateral meniscal root tears. Medial meniscal extrusion was positively correlated with mechanical alignment. (r = 0.200, p = 0.001). The mean mechanical alignment was 4.05 ± 2.24 degree varus in the patients with medial meniscus posterior root tear and 1.88 ± 3.55 degree valgus in those with lateral meniscus posterior root tear. The International Knee Documentation Committee (IKDC) classification results revealed that chondrosis was generally grade 2 (n = 138, 49.8%) in the medial compartment, and grade 1 (n = 121, 43.7%) in the lateral compartment.

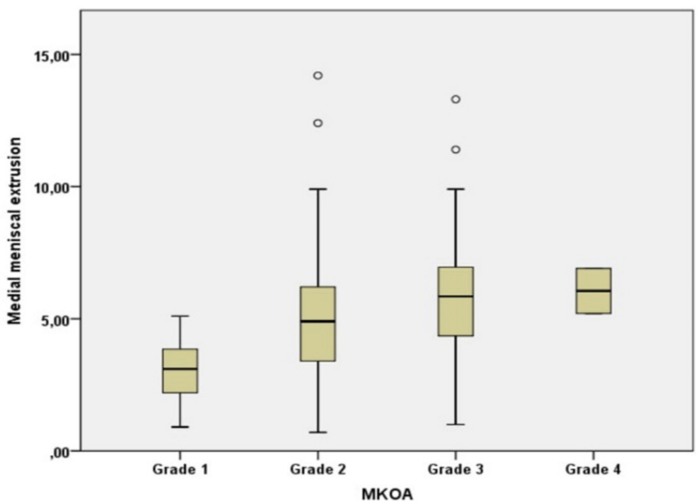

Figure 5. Group mean analysis between the presence of medial knee osteoarthritis and the severity of medial meniscal extrusion

There were 79 patients with SIFK, 198 patients without SIFK in our cohort. The patients with SIFK were older compared to those without (mean age: 59.33 ± 10.85 vs 55.81 ± 11.18 years; p = 0,018). There was no statistically significant difference in meniscal extrusion with respect to the presence of SIFK (mean medial meniscal extrusion: without SIFK 4.90 ± 2.07 mm vs with SIFK 4.94 ± 2.53 mm; p = 0.914) (Table 6).

Most of the patients with severe meniscal extrusion were female (meniscal extrusion severity: 76% female and 24% male) (Table 3). Horizontal meniscus tear did not provide significant contribution to explain the variation in the degree of meniscal extrusion. A horizontal meniscal tear was observed in 10% of mild meniscal extrusion, 17.4% of moderate ones and 10.4% of severe ones. Only 0.8% of the patients with severe meniscal extrusion had grade 1 MKOA. All patients with grade 4 MKOA had severe meniscal extrusion, however since there were only a few patients with grade 4 MKOA, they comprised just 1.6% of the patients with severe meniscal extrusion. Severe meniscal extrusion was observed in 66.3% of the patients with grade 3 MKOA and 47.1% of the patients with grade 2 MKOA.

In the patients with mild meniscal extrusion, the medial meniscal extrusion was 2.22 ± 0.63 and the mechanical alignment was 3.22 ± 1.5; in those with moderate meniscal extrusion, the meniscal extrusion was 4.04 ± 0.59 mm and the mechanical alignment was 4.16 ± 2; in those with severe meniscal extrusion, the mean medial meniscal extrusion was 6.63 ± 1.88 and the mechanical alignment was 4.3 ± 2.27 (p < 0.001).

There was a concomitant ACL rupture in 21.6% of the patients having severe meniscal extrusion. In the patients having medial meniscus posterior root tear, the medial meniscal extrusion was 4.89 ± 2.22 mm and the mechanical alignment was 4.05 ± 2.24. The lateral meniscal extrusion was 3.2 ± 1.7 mm and the mean mechanical alignment was -1.88 ± 3.55 in the patients with lateral Meniscus posterior root tear.

The average age was 50.94 ± 13.04 years, the medial meniscal extrusion was 3.09 ± 1.1 mm, and the mechanical alignment was 3.63 ± 2.0 in the patients with grade 1 MKOA. The average age was 58.62 ± 10.27 years, the medial meniscal extrusion was 5.04 ± 2.25 mm, and the mechanical alignment was 4.09 ± 2.58 in the patients with grade 2 MKOA. The average age was 57.37 ± 10.39, years, the medial meniscal extrusion was 5.8 ± 2.01 mm, and the mechanical alignment was 3.83 ± 2.3 in the patients with grade 3 MKOA. The mean age was 58.0 ± 10.31, years, the mean medial meniscal extrusion was 6.05 ± 1.2 mm, and the mean mechanical alignment was 5.1 ± 0.2 in the patients with grade 4 MKOA (Table 4).

A statistically significant difference was detected between MKOA groups with respect to age and medial meniscal extrusion (p < 0.001). In general, low-grade chondrosis and low-grade SIFK were present among the patients having low-grade meniscal extrusion.

In the patients with mild meniscal extrusion, the average age was 52.66 ± 13.1 and the mechanical alignment was 3.22 ± 1.5. In the patients with moderate meniscal extrusion, the average age was 58.07 ± 10.39 and the mechanical alignment was 4.16 ± 2.47. In the patients with severe meniscal extrusion, the average age was 57.68 ± 10.82 and the mechanical alignment was 4.3 ± 2.27 (Figure 6). The correlation between medial meniscal extrusion and age (r = 0.128 p = 0.036), and mechanical alignment (r = 0.200 p = 0.001) variables was significant.

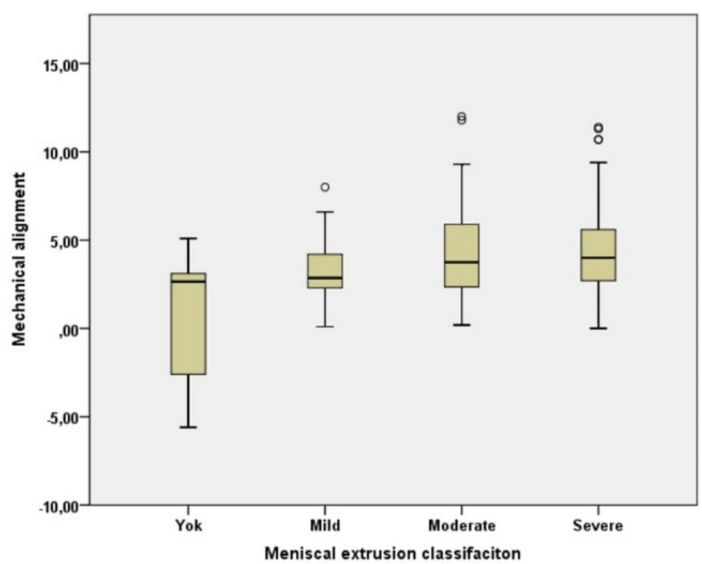

Figure 6. Group mean analysis between the severity of medial meniscal extrusion and the degree of mechanical alignment

Table 1. Summary of significance of Meniscus posterior root tear in various knee joint pathologies

Variable		Meniscus_posterior_root_tear			p
		Medial n(%)	**Lateral n(%)**	**Both n(%)**	
SIFK	None	189(71.3)	3(60)	6(85.7)	0.600
	Present	76(28.7)	2(40)	1(14.3)	
Meniscal extrusion clas-sifaciton	None	5(1.9)	5(100)	0(0)	<0.001
	Mild	50(18.9)	0(0)	0(0)	
	Moderate	91(34.3)	0(0)	1(14.3)	
	Severe	119(44.9)	0(0)	6(85.7)	
MKOA	Grade 1	50(18.9)	0(0)	1(14.3)	0.886
	Grade 2	130(49.1)	4(80)	4(57.1)	
	Grade 3	83(31.3)	1(20)	2(28.6)	
	Grade 4	2(0.8)	0(0)	0(0)	
LKOA	Grade 1	119(44.9)	1(20)	1(14.3)	0.067
	Grade 2	90(34)	4(80)	5(71.4)	
	Grade 3	56(21.1)	0(0)	1(14.3)	
	Grade 4	0(0)	0(0)	0(0)	
Gender	Female	206(77.7)	2(40)	5(71.4)	0.132
	Male	59(22.3)	3(60)	2(28.6)	
Lateralizasyon	Right	122(46)	1(20)	3(42.9)	0.506
	Left	143(54)	4(80)	4(57.1)	
Additional lateral meniscal tear	None	231(87.2)	4(80)	7(100)	0.870
	Horizontal	18(6.8)	0(0)	0(0)	
	Vertical	9(3.4)	1(20)	0(0)	
	Longitudinal	4(1.5)	0(0)	0(0)	
	Complicated	2(0.8)	0(0)	0(0)	
	Bucked handle	1(0.4)	0(0)	0(0)	
Additional medial meniscal tear	None	208(78.5)	5(100)	7(100)	0.975
	Horizontal	34(12.8)	0(0)	0(0)	
	Vertical	4(1.5)	0(0)	0(0)	
	Longitudinal	9(3.4)	0(0)	0(0)	
	Complicated	8(3)	0(0)	0(0)	
	Bucked handle	2(0.8)	0(0)	0(0)	
Additional Ligament Injuries to the Knee	None	185(69.8)	4(80)	2(28.6)	<0.001
	ACL	48(18.1)	0(0)	1(14.3)	
	PCL	3(1.1)	0(0)	0(0)	
	MCL	10(3.8)	0(0)	0(0)	
	LCL	8(3)	1(20)	1(14.3)	
	ACL+LCL	3(1.1)	0(0)	1(14.3)	
	ACL+PCL+LCL+MCL	1(0.4)	0(0)	0(0)	
	ACL+PCL	5(1.9)	0(0)	1(14.3)	
	ACL+MCL	1(0.4)	0(0)	0(0)	
	MCL+LCL	0(0)	0(0)	1(14.3)	
	LCL+PCL	1(0.4)	0(0)	0(0)	

Pearson chi-square test was used

Table 2. Summary of data regarding MKOA grade and relationship to various knee joint pathologies

Variable		MKOA				p
		Grade 1 n(%)	Grade 2 n(%)	Grade 3 n(%)	Grade 4 n(%)	
Meniscus posterior root tear	Medial	50(98)	130(94.2)	83(96.5)	2(100)	0.886
	Lateral	0(0)	4(2.9)	1(1.2)	0(0)	
	Both	1(2)	4(2.9)	2(2.3)	0(0)	
SIFK	None	38(74.5)	101(73.2)	57(66.3)	2(100)	0.500
	Present	13(25.5)	37(26.8)	29(33.7)	0(0)	
Meniscal extrusion classifaciton	None	0(0)	8(5.8)	2(2.3)	0(0)	<0.001
	Mild	25(49)	21(15.2)	4(4.7)	0(0)	
	Moderate	25(49)	44(31.9)	23(26.7)	0(0)	
	Severe	1(2)	65(47.1)	57(66.3)	2(100)	
Gender	Female	42(82.4)	103(74.6)	66(76.7)	2(100)	0.603
	Male	9(17.6)	35(25.4)	20(23.3)	0(0)	
Lateralizasyon	Right	28(54.9)	60(43.5)	38(44.2)	0(0)	0.287
	Left	23(45.1)	78(56.5)	48(55.8)	2(100)	
Additional lateral meniscaltear	None	46(90.2)	120(87)	74(86)	2(100)	0.954
	Horizontal	2(3.9)	11(8)	5(5.8)	0(0)	
	Vertical	2(3.9)	4(2.9)	4(4.7)	0(0)	
	Longitudinal	1(2)	1(0.7)	2(2.3)	0(0)	
	Compliced	0(0)	2(1.4)	0(0)	0(0)	
	Bucked handle	0(0)	0(0)	1(1.2)	0(0)	
Additional medial meniscal tear	None	32(62.7)	120(87)	67(77.9)	1(50)	0.082
	Horizontal	9(17.6)	14(10.1)	10(11.6)	1(50)	
	Vertical	2(3.9)	1(0.7)	1(1.2)	0(0)	
	Longitudinal	3(5.9)	3(2.2)	3(3.5)	0(0)	
	Compliced	4(7.8)	0(0)	4(4.7)	0(0)	
	Bucked handle	1(2)	0(0)	1(1.2)	0(0)	
Ligament Injuries to the Knee	None	36(70.6)	98(71)	55(64)	2(100)	0.902
	ACL	10(19.6)	23(16.7)	16(18.6)	0(0)	
	PCL	0(0)	1(0.7)	2(2.3)	0(0)	
	MCL	1(2)	6(4.3)	3(3.5)	0(0)	
	LCL	1(2)	5(3.6)	4(4.7)	0(0)	
	ACL+LCL	0(0)	1(0.7)	3(3.5)	0(0)	
	ACL+PCL+LCL+MCL	1(2)	0(0)	0(0)	0(0)	
	ACL+PCL	1(2)	3(2.2)	2(2.3)	0(0)	
	ACL+MCL	0(0)	0(0)	1(1.2)	0(0)	
	MCL+LCL	0(0)	1(0.7)	0(0)	0(0)	
	LCL+PCL	1(2)	0(0)	0(0)	0(0)	

Pearson chi-square test was used

Table 3. Summary of data regarding SIFK grade and relationship to various knee joint pathologies

Variable		SIFK		p
		None n(%)	Present n(%)	
Meniscal extrusion classifaciton	None	6(3)	4(5.1)	0.748
	Mild	34(17.2)	16(20.3)	
	Moderate	66(33.3)	26(32.9)	
	Severe	92(46.5)	33(41.8)	
MKOA	Grade 1	38(19.2)	13(16.5)	0.500
	Grade 2	101(51)	37(46.8)	
	Grade 3	57(28.8)	29(36.7)	
	Grade 4	2(1)	0(0)	
LKOA	Grade 1	84(42.4)	37(46.8)	0.777
	Grade 2	73(36.9)	26(32.9)	
	Grade 3	41(20.7)	16(20.3)	
	Grade 4	0(0)	0(0)	
Gender	Female	153(77.3)	60(75.9)	0.813
	Male	45(22.7)	19(24.1)	
Lateralizasyon	Right	94(47.5)	32(40.5)	0.293
	Left	104(52.5)	47(59.5)	
Additional lateral meniscal tear	None	178(89.9)	64(81)	0.004
	Horizontal	7(3.5)	11(13.9)	
	Vertical	8(4)	2(2.5)	
	Longitudinal	4(2)	0(0)	
	Compliced	0(0)	2(2.5)	
	Bucked handle	1(0.5)	0(0)	
Additional medial meniscal tear	None	156(78.8)	64(81)	0.803
	Horizontal	24(12.1)	10(12.7)	
	Vertical	4(2)	0(0)	
	Longitudinal	7(3.5)	2(2.5)	
	Compliced	6(3)	2(2.5)	
	Bucked handle	1(0.5)	1(1.3)	
Ligament Injuries to the Knee	Yok	135(68.2)	56(70.9)	0.157
	ACL	37(18.7)	12(15.2)	
	PCL	3(1.5)	0(0)	
	MCL	4(2)	6(7.6)	
	LCL	10(5.1)	0(0)	
	ACL+LCL	2(1)	2(2.5)	
	ACL+PCL+LCL+MCL	1(0.5)	0(0)	
	ACL+PCL	3(1.5)	3(3.8)	
	MCL+LCL	1(0.5)	0(0)	
	LCL+PCL	1(0.5)	0(0)	

Pearson chi-square test was used

Table 4. Analysis of quantitative variables according to MKOA

Variable	MKOA				p
	Grade 1	Grade 2	Grade 3	Grade 4	
	Ort±SS	Ort±SS	Ort±SS	Ort±SS	
Age	50.94±13.04 (a)	58.62±10.27 (b)	57.37±10.39 (b)	58±110.31 (ab)	<0.001
Medial meniscal extrusion(millimeter)	3.09±1.1 (a)	5.04±2.25 (b)	5.8±2.01 (c)	6.05±1.2 (c)	<0.001
Size of tibia osteophyte(millimeter)	2±.	2.33±0.86	2.72±1.23	4.2±1.41	0.009
Lateral meniscal extrusion(millimeter)	0±.	3.45±1.13	3.07±1.9	.±.	0.104
Femorotibial angle	3.63±2	4.09±2.58	3.83±2.3	5.1±0.28	0.556

One-way analysis of variance was used. (abc): A common letter as a line indicates statistical insignificance

Table 5. Correlation between medial meniscal extrusion and quantitative variables

Variable	Mean±Sd	Median [C1-C3]	r	p
Medial meniscal extrusion(millimeter)	4.91±2.2	4.7[0.7-14.2]	-	-
Age	56.82±11.18	56[21-86]	0.128	0.036
Size of tibia osteophyte(millimeter)	2.51±1.06	2.4[1-6.7]	0.042	0.584
Lateral_meniscal_extrusion(millimeter)	3.07±1.56	2.85[0-5.3]	0.497	0.256
Femorotibial angle	3.93±2.39	3.6[-5.6-12]	0.200	0.001
Pearson correlation coefficient was used				

Table 6. Analysis of quantitative variables according to SIFK

Variables	SIFK		P
	None	Present	
	Mean ±SD	Median ±SD	
Age(year)	55.81±11.18	59.33±10.85	0.018
Medial meniscal extrusion(millimeter)	4.9±2.07	4.94±2.53	0.914
Size of tibia osteophyte (millimeter)	2.53±1	2.48±1.19	0.760
Lateral meniscal extrusion(millimeter)	3.03±1.51	3.17±2.06	0.905
Femoro tibial angle (degree)	3.89±2.3	4.04±2.62	0.644
The significance test of the difference between the two means was used			

According to the MKOA grades of the patients, the mean medial meniscal extrusion was detected as 3.09 ± 1.1 in Grade 1, 5.04 ± 2.25 in Grade 2, 5.8 ± 2.01 in Grade 3, and 6.05 ± 1.2 in Grade 4 ($p < 0.001$).

The mean tibial osteophyte size in the patients with grade 4 MKOA was 4.2 ± 1.41 and was larger than the other groups with different grades of MKOA ($p = 0.009$). According to the results obtained from the ROC analysis, the meniscal extrusion of >=3.3 (cut-off) represented the MKOA risk. The test sensitivity at this cut-off was 63.33%, and the specificity was 63.33% (AUC: 0.6522 $p < 0.001$).

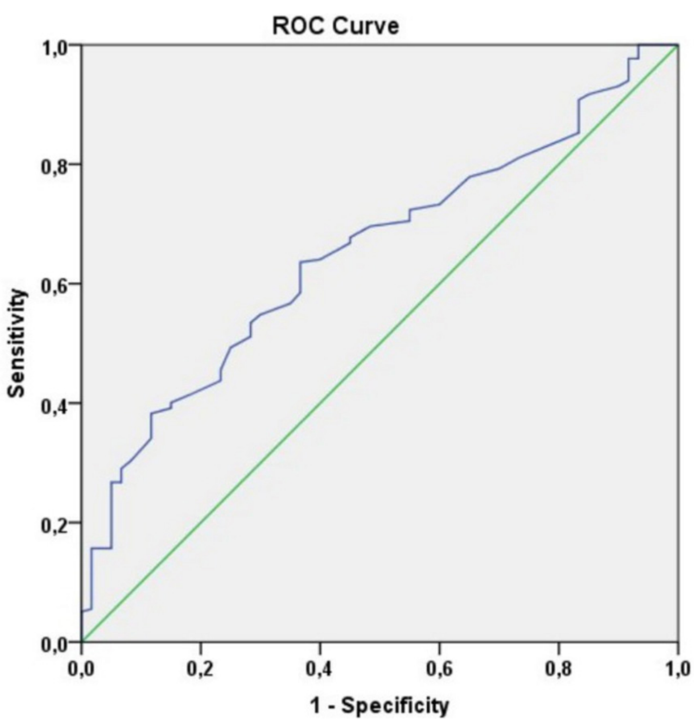

Figure 7. Receiver operating characteristic (ROC) curve using the meniscal extrusion in mm as predicting variable

Discussion

According to our best knowledge, the present research is the first study to show the incidence of meniscal root tear and concomitant pathologies in such a large MRI series. We found that in the patients with high-grade meniscal extrusion, high-grade chondrosis, malalingment, and SIFK lesions were observed. Hence it could be concluded that meniscus posterior root tear (MPRT) induces meniscal extrusion (MME), which causes subchondral insufficiency fracture of the knee, and gonarthrosis. The incidence of meniscal tears is estimated to be around 60 per 100,000, however the actual frequency is expected to be much higher. Jarraya et al. reported that more than 75% of patients suffering symptomatic osteoarthritis had meniscus injury [18]. In our study, 277 meniscus root tears were detected in 10980 MRI and the incidence was 2.52%.

Although degenerative meniscal disease was the main reason for medial meniscus posterior root tear, lateral meniscus posterior root tear (LMPRT) usually occurs as an outcome of trauma and it has been reported to be observed in 7-10% of patients suffering an ACL injury [19–22]. In the present study, the average age was lower in the patients having lateral meniscus posterior root tear (53 ± 10.93 years) than in those having medial meniscus posterior root tear (56.76 ± 11.05 years). The reconstruction of ACL is performed for the prevention of knee instability due to excessive anterior tibial translation and also for the protection of the medial meniscus (MM) from other injuries because MM acts as a secondary stabilizer of anterior tibial translation in knees with ACL-deficiency. The results of our study showed that lateral meniscus root tear was mostly concomitted by additional Ligament Injuries to the Knee. The most frequent concomitant ligament injury of meniscal root tear was ACL rupture.

Costa et al [23] examined the relationship between the prevalence of MME and meniscal pathology and determined that there was an association between MME and meniscal degeneration, radial, oblique, complex, and root tears. Besides, they also stated that large radial tears, complex tears, and posterior root tears leaded to maximal meniscal extrusion [23]. Hence, longitudinal and horizontal tears were not linked to extensive meniscal extrusion [23]. In our study, accompanying the medial meniscal root tear, the additional medial meniscal tear was a horizontal tear (12.8%), the additional lateral meniscal tear was again a horizontal tear (6.8%). An additional lateral meniscal vertical tear was found in one of the ten patients without meniscal extrusion; other nine had neither medial nor lateral additional meniscus injury. MRI studies demonstrate that there is a more powerful correlation between meniscal tears and joint space narrowing and the existence of osteophytes [2,24].

Incorrect alignment can elevate the load transferred to the meniscus, which can cause extrusion. Varus and valgus angulation relates to medial and lateral meniscal extrusion, respectively [25]. Previous MRI studies have shown that there is a powerful correlation between meniscal extrusion and joint space narrowing compared to meniscal tears and cartilage defects [26–28]. All the patients included in our study had meniscal root tear. The mean mechanical alignment was 4.05 ± 2.24 varus in the patients with MMPRT, and -1.88 ± 3.55 valgus in those with lateral meniscus root.

Meniscus root tears inhibits the circular stress of the meniscus, as a result of which continuous compression forces within the knee may lead to displacement or extrusion of the meniscus. It has been shown that meniscal tears and degenerative changes in the meniscus are predisposing factors.

Meniscal extrusion contributes the formation of tibial femoral cartilage damage and knee misalignment. It has been reported that meniscal extrusion are seen in elderly patients with symptomatic knee osteoarthritis [25]. Among patients with advanced age, meniscal extrusion appears before the degenerative joint disease to develop. Besides, certain studies have revealed that MME is associated with knee pain. Knee pain was commonly observed in osteoarthritic patients with MME compared to those without [29,30]. In the present study, in the patients having mild meniscal extrusion classification, the average age was lower (52.66 ± 13.1) and mechanical alignment was closer to the midline (3.22 ± 1.5). It was found that the size of tibia osteophyte was not correlated with meniscal extrusion.

In the patients with mild meniscal extrusion classification, 50% Grade 1 MKOA, 42% Grade 2 MKOA, 62% Grade 1 LKOA and 26% Grade 2 LKOA were detected, whereas when the meniscal extrusion classification was severe, 52% Grade 2 MKOA, 45.6% Grade 3 MKOA, 43.2% Grade 2 LKOA and 24% Grade 3 LKOA were determined.

Meniscal extrusion independently predicts the progression of OA disease [31,32] and MME alone is powerfully correlated to the loss of tibia-femoral cartilage [33–36]. Many studies in the literature report that an MME of ≥ 3 mm on MRI is significantly linked to articular cartilage degeneration [37,38]. The ROC analysis performed in our study revealed that the cut-off value was 3.3 mm.

Although the pathogenesis of OA has not been fully clarified, the role MME plays is of importance because it may be a precursor for the development or subsequent emergence of OA.

Knee malalignment meniscus causes inadequate load distribution between the knee joint cartilage and subchondral bone, which can cause injury and expedite OA progression [39]. Crema et al. stated that varus malalignment could be regarded as an independent factor associated with meniscal extrusion [33]. Further, Lefevre et al. reported the same finding indicating there was an association between varus malalignment and MME [40]. However, in two studies conducted by Chang et al. and Erquicia et al. in which 169 and 61 varus knees, respectively, were included, varus malalignment was found to be not associated with meniscal extrusion.

In the present study, mechanical alignment was higher in the patients with Grade 4 MKOA, those with severe meniscal extrusion classification and those with SIFK. (Grade 4: 5.1 ± 0.28, Grade 1: 3.63 ± 2, Severe: 4.3 ± 2.27, mild 3.22 ± 1.5, with SIFK 4.04 ± 2.62, without SIFK 3 .89 ± 2.3).

Limitations

MRI was conducted while the patient was in the supine position without putting weight on the knee. It is challenging to detect LMPRT with MRI findings when used alone, due to its relatively low sensitivity, and the MRI technique and imaging plane to be used to reliably detect meniscal root tears is controversial. Despite the fact that MRI is a significant diagnostic tool to diagnose meniscal root tears, one of the primary downsides of two-dimensional MRI measurements is that it requires the use of specific coronal and sagittal slices. In relation to that, MRI has been reported to give intolerably high rate of false-negative results, depending on meniscus size's length, width, and height in its curved regions (eg, trunk and anterior and posterior horns) [6]. For this reason, a three-dimensional imaging technology based on MRI has been developed so that the size of the meniscus and its position relative to the tibia can be measured.

It appears that 3D MRI technology has recently been used for the determination of meniscal volume and quantification of the whole meniscus [28]. Nonetheless, there is no clear evidence for the superiority of the 3D method over the 2D method.

Conclusion

There was a significant correlation between medial meniscal extrusion and age [r = 0.128 p = 0.036] and mechanical alignment [r = 0.200 p = 0.001]. The patients with low-grade meniscal extrusion were mostly observed to have low-grade SIFK and low-grade chondrosis as well. In the meniscus patients included in our study, high-grade meniscal extrusion was found to be in relation with high-grade SIFK lesions and unicompartmental high-grade chondrosis. In conclusion, in knee MR imaging, the amount of meniscal extrusion in meniscal root tear correlates with subchondral insufficiency fracture and the degree of chondrosis.

Conflict of interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical approval

Tokat Gaziosmanpasa University medical faculty ethics committee approval code 22-kaek - 018

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